Fishery Data Series No. 17-05

West Cook Inlet (Theodore and Lewis Rivers) Chinook and Coho Salmon Escapement Studies, 2012–2014

by

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and

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February 2017

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat or long
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

FISHERY DATA SERIES NO. 17-05

WEST COOK INLET (THEODORE AND LEWIS RIVERS CHINOOK AND COHO SALMON ESCAPEMENT STUDIES, 2012–2014

by
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ABSTRACT

In 2011, the Alaska Board of Fisheries (BOF) designated Chinook salmon (*Oncorhynchus tshawytscha*) in the Northern District of Cook Inlet, which includes the Theodore and Lewis rivers, to be a stock of yield concern. The purpose of this project was to determine whether the current escapement survey method of a single aerial survey, conducted annually during peak Chinook salmon spawning, provides a reliable index to manage these fisheries. From 2012 to 2014, resistance board weirs were installed on the Theodore and Lewis rivers to monitor Chinook salmon escapement for comparison to the aerial index survey. Weir operation was extended through the fall to enumerate coho salmon (*O. kisutch*) for the 2013 and 2014 runs. Because weirs on the Theodore and Lewis rivers had numerous inoperable periods when missed passage could not be estimated for 2013 (Lewis River) and 2014 (Lewis and Theodore rivers), reliable escapement estimates could not be made for these years. The only year when a comparison between the weir count and the aerial index survey could be made for the Lewis River was 2012. Of the 58 Chinook salmon that passed the Lewis River weir in 2012, 28 (48%) were counted above the weir by aerial survey. For the Theodore River, 129 (22%) and 434 (69%) of the 577 and 630 Chinook salmon that passed the weir were accounted for in the aerial surveys in 2012 and 2013, respectively. On the Theodore River in 2013, a total of 1,560 coho salmon passed the weir between 20 July and 31 August. On the Lewis River in 2013, a total of 413 coho salmon passed the weir between 30 July and 31 August. Coho salmon counts on the Theodore and Lewis rivers in 2014 were incomplete due to several periods when the weirs were inoperable because of high water.

Key words: Theodore River, Lewis River, Northern Cook Inlet, Chinook salmon, *Oncorhynchus tshawytscha*, coho salmon, *O. kisutch*, escapement, weir, aerial survey

INTRODUCTION

The primary goals of this project were to estimate the inriver escapements of Chinook salmon stocks in the Theodore and Lewis rivers and to determine whether a single annual helicopter survey of both rivers provides reliable indices of escapement to manage these fisheries. Weirs were installed on both the Theodore and Lewis rivers during the 2012–2014 seasons to estimate escapements of Chinook salmon. As done in the past, a single aerial survey was flown each of these years to enumerate the number of spawning salmon as well. The Theodore and Lewis rivers weir counts and the independent aerial surveys during peak spawning were compared to verify that the aerial survey provides a reliable index of escapement (i.e., one that can be used consistently and with consistent estimates).

In 2011, the Alaska Board of Fisheries (BOF) designated Chinook salmon in the Northern Districts of Cook Inlet, which include the Theodore and Lewis rivers, to be a stock of yield concern. This required the development of an action plan to conservatively manage the fisheries while research is continued to better understand and protect these stocks. This action by the BOF requires regulatory closures of all sport fishing for Chinook salmon in the Theodore, Lewis, and other NCI rivers if low escapement numbers are determined. Failure to meet aerial index escapement goals (500–1,700 fish for Theodore River and 250–800 fish for Lewis River) from 2007 to 2009, led to the closure of the Chinook salmon fishery by management in 2010 and then closure by regulation beginning in 2011 to present (Oslund et al. 2013) (Table 1).

The Theodore and Lewis rivers are accessible by a road that connects to nearby communities. Due to the vicinity of these roads, both the Theodore and Lewis rivers are subject to both sport fishing effort as well as mineral exploration from nearby residents. These rivers flow into Cook Inlet, which is the location of a mixed-stock fishery used by subsistence and commercial fishing. The number of salmon captured in the NCI mixed-stock fisheries that are bound for the Theodore and Lewis rivers is not known. The headwaters of the Theodore and Lewis rivers is also the location of the proposed Chuitna coal mine.

Table 1.–West Cook Inlet drainage Chinook salmon aerial escapement index surveys by fishery, 1979–2014.

Year	Chuitna River	Theodore River	Lewis River	Coal Creek	Other streams [a]	Total WCI
1979	1,246	512	546	[b]	236	2,540
1980	[b]	[b]	[b]	[b]	[b]	[b]
1981	1,362	535	560	[b]	1,144	3,601
1982	3,438	1,368	606	[b]	1,972	7,384
1983	4,043	1,519	[b]		[b]	5,562
1984	2,845	1,251	947	[b]	[b]	5,043
1985	1,600	1,458	861	[b]	700	4,619
1986	3,946	1,281	722	[b]	165	6,114
1987	[b]	1,548	875	[b]	[b]	2,423
1988	3,024	1,906	616	[b]	[b]	5,546
1989	990	1,026	452	[b]	[b]	2,468
1990	480	642	207	[b]	[b]	1,329
1991	537	508	303	[b]	[b]	1,348
1992	1,337	1,053	445	[b]	[b]	2,835
1993	2,085	1,110	531	[b]	156	3,882
1994	1,012	577	164	[b]	368	2,121
1995	1,162	694	146	221	[b]	2,223
1996	1,343	368	257	424	[b]	2,392
1997	2,232	1,607	777	471	[b]	5,087
1998	1,869	1,807	626	503	[b]	4,805
1999	3,721	2,221	675	1195	[b]	7,812
2000	1,456	1,271	480	757	[b]	3,964
2001	1,501	1,237	502	1,154	[b]	4,394
2002	1,394	934	439	882	[b]	3,649
2003	2,339	1,059	878	698	[b]	4,974
2004	2,938	491	1000	609	[b]	5,038
2005	1,307	478	441	504	[b]	2,730
2006	1,911	958	341	996	[b]	4,206
2007	1,180	486	0 [c]	773	[b]	2,439
2008	586	345	120	[b]	[b]	1,051
2009	1,040	352	111	119 [d]	[b]	1,622
2010	735 [e]	202	56 [e]	[b]	[b]	993
2011	719 [e]	327 [e]	92 [e]	373	[b]	1,511
2012	[b] [e]	179 [e]	107 [e]	[b]	[b]	286
2013	[b] [e]	476 [e]	61 [e]	[b]	[b]	537
2014	[b] [e]	312 [e]	61 [e]	[b]	[b]	373
Average						
1979–2014	1,786	917	441	645	677	3,340
2005–2014	1,068	411	139	553	–	1,575
2012–2014	–	322	76	–	–	399
SEG [f]	1,200–2,900	500–1,700	250–800			

Note: An en dash means that the value can't be computed due to limitations of the data.

[a] May include Olsen, Nikoli, Coal, Straight, Bishop, Drill, and Scarp creeks.

[b] No count conducted because of turbid water.

[c] River diverged into open muskeg one-half mile below the bridge. No water in mainstem.

[d] Mainstem too glacially turbid to count. Counts only conducted above forks.

[e] Closed to sport fishing.

[f] SEG is the sustainable escapement goal.

The Theodore and Lewis rivers Chinook salmon escapement monitoring project was a 3-year project funded through a grant from the Alaska Sustainable Salmon Fund (AKSSF). The Alaska Department of Fish and Game (ADF&G) was able to provide additional funds to extend operations in 2013–2014 through mid-September in order to enumerate, determine run timing, and collect additional information about coho salmon in these systems.

CHINOOK SALMON

The Theodore and Lewis rivers, near the village of Tyonek (Figure 1), have historically contributed to a subsistence fishery, a commercial setnet fishery in the Northern District, and a sport fishery for Chinook salmon (Ivey et al. 2007). Effective 1993, the BOF made a positive customary and traditional use finding for Chinook salmon in the Tyonek Subdistrict (Alaska Administrative Code 5 AAC 01.566 [a][1][A]), and set a harvest necessary for subsistence at 850–3,600 Chinook salmon (ADF&G 1995:33). Some marine harvest of the Chuitna, Theodore, and Lewis rivers Chinook salmon stocks probably occurs in the adjacent Northern District setnet Chinook salmon fishery, but the stock contribution of this fishery has never been fully determined (Cook Inlet Staff 2011). Since 1979, the Theodore and Lewis rivers Chinook salmon fisheries have been managed based on the results of a single aerial survey conducted annually during the peak of Chinook salmon spawning. A steady decline in escapements as measured by the aerial survey index has occurred over the past 5 years in both rivers (Table 1). Due to these low indices of escapement, sport fishing for Chinook salmon in the Theodore and Lewis rivers is currently prohibited.

COHO SALMON

Very little is known about the run timing or inriver escapement of coho salmon on the Theodore and Lewis rivers; the first time these systems were monitored for escapement using resistance board weirs was in this study in 2013. West Cook Inlet coho salmon harvest records from 1977 to 2013, provide an overview of annual sport fish harvest (Table 2).

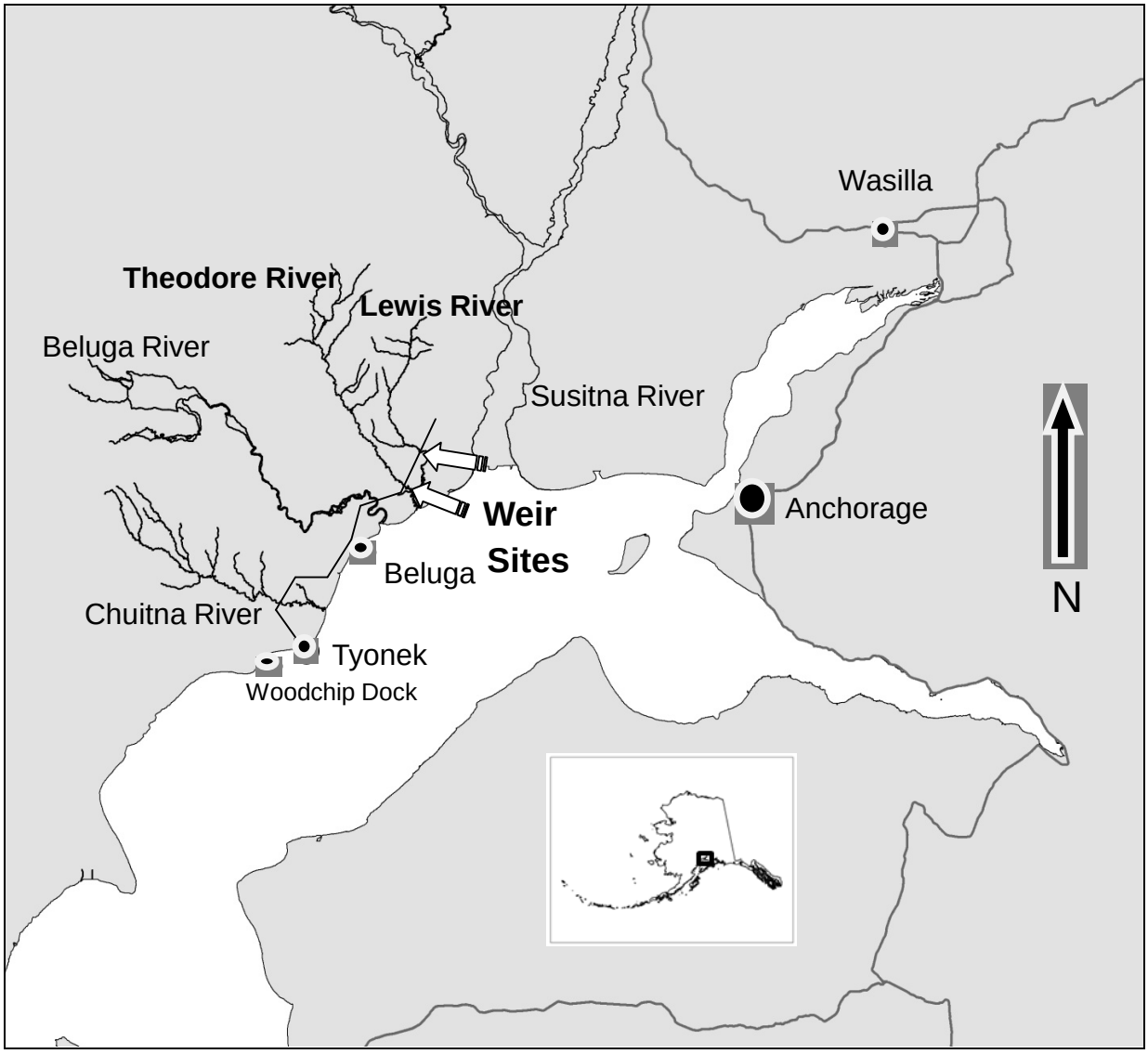

Figure 1.–Location of Theodore and Lewis rivers and weir sites in relation to other features in Upper Cook Inlet.

Table 2.–West Cook Inlet drainage coho salmon sport harvest by fishery, 1977–2013.

Year	Chuitna River	Beluga River	Theodore River	Lewis River	Kustatan River	Polly Creek	Big River Lakes [a]	Silver Salmon Creek	Other Susitna River–N. Foreland	Other South of N. Foreland	Other [b]	Total
1977	316		113	103								532
1978	277		101	0								378
1979	287		50	0								337
1980	258		370	0								628
1981	594		10									604
1982	220		115			410						745
1983	554		10		1,800	188						2,552
1984	898		137		1,646							2,681
1985	1,095		261	75	4,889							6,320
1986	815		168		3,239							4,222
1987	1,684		996	145	5,723							8,548
1988	782		400	0	6,221							7,403
1989	1,228	419	502	112	5,413						9	7,683
1990	1,113		198	33	4,584		88					6,016
1991	1,791		513	181	5,768							8,253
1992	1,547	243	421		4,494	332						7,037
1993	1,313		236	194	6,457		158			751	1,217	10,326
1994	559		521		5,259		25			268	1,615	8,247
1995	1,407		372		4,237	641	75			559	891	8,182
1996	1,263		361		6,266	170	600		741	1,858	171	11,430
1997	1,156		187		3,605		305		574	632	33	6,492
1998	2,348		380		3,999		264		650	382	137	8,160
1999	1,614		290		3,178		463		1,282	2,047	465	9,339
2000	1,872		1,161		5,699		325		1,134	1,521		11,712
2001	3,284		1,029		4,920		508		1,210	2,998		13,949
2002	2,586		1,208	200	5,795		490		1,725	761	615	13,380
2003	1,467	426	225	197	3,967	190	2,830	2,269	429	1,611	628	14,239
2004	1,655	520	645	90	3,984	39	2,648	1,389	225	3,471	1,103	15,769
2005	972	120	229	524	3,551		3,916	1,568	491	913	288	12,572

-continued-

Table 2.–Page 2 of 2.

Year	Chuitna River	Beluga River	Theodore River	Lewis River	Kustatan River	Polly Creek	Big River Lakes [a]	Silver Salmon Creek	Other Susitna River–N. Foreland	Other South of N. Foreland	Other [b]	Total
2006	531	313	282	177	3,556	73	3,953	997	360	1,538	160	11,940
2007	1,577	537	811	82	4,057	45	1,644	1,041	792	820	1,174	12,580
2008	1,401	490	31	29	3,868	285	3,560	356	122	967	3,564	14,673
2009	707	154	313	73	2,639	106	3,032	1,133	1,009	548	87	9,801
2010	257	244	178	77	2,832	79	2,667	714	451	971	960	9,430
2011	425	512	45	9	1,876	28	1,270	640	852	419	216	6,292
2012	770	338	116	27	2,136	0	1,634	419	909	974	0	7,323
Average 2008–2012	712	323	137	177	2,670	127	2,433	1,019	669	776	965	9,504
2013	375	48	328	92	2,550	0	2,293	224	427	1,269	92	7,698

Source: Alaska Sport Fishing Survey database [Internet]. 1996– . Anchorage, AK: Alaska Department of Fish and Game, Division of Sport Fish. Available from: http://www.adfg.alaska.gov/sf/sportfishingsurvey/.

OBJECTIVES AND TASKS

Objectives

The objectives for the West Cook Inlet salmon weir project were as follows:

1) Count the number of adult Chinook salmon in the Theodore and Lewis rivers that pass through each weir from late May through early August (2012) or early June through mid-September (2013–2014).
2) Estimate the age, sex, and length (ASL) composition of the adult Chinook salmon runs to the Theodore and Lewis rivers from late May or early June through early August 2012–2014 such that the estimates are within ±8 percentage points of the true values 95% of the time.
3) For the Chinook salmon escapement, compare yearly aerial helicopter survey index counts with weir counts on the Theodore and Lewis rivers to assess whether aerial surveys provide a reliable index of escapement.
4) Count the number of adult coho salmon in the Theodore and Lewis rivers that pass through each weir from early June to mid-September 2013–2014.
5) Estimate the ASL composition of the coho salmon runs to the Theodore and Lewis rivers from mid-July through mid-September 2013–2014 such that the estimates are within ±12 percentage points of the true values 95% of the time.

Tasks

1) Identify and count all species of fish that move through the live trap from weir installation until weir removal.
2) Estimate mean length-at-age and age-by-sex composition for the Theodore and Lewis rivers Chinook and coho salmon runs.
3) Record water temperature twice daily and water clarity and level once daily.
4) Collect 100 coho salmon genetic samples from the Theodore and Lewis rivers in 2013 and 2014.
5) Collect genetic samples of Chinook salmon concurrent with ASL proportions.
6) Radiotag 57 Chinook salmon at the Theodore River weir proportionally throughout the run in 2013 such that the tags are all deployed at the time of the aerial index survey.
7) Determine spawning distribution of Chinook salmon on the Theodore River in 2013 using aerial radiotelemetry surveys.

METHODS

STUDY SITES

Theodore River

The Theodore River originates in the Western Foothills of Little Mount Susitna. The river flows south, approximately 51.5 river kilometers (RKM) or 32 river miles (RM) before entering Cook Inlet. A resistance board weir was installed at lat 61°15′55.20″N, long 150°52′40.25″W, which is

approximately 9.7 RKM (6 RM) from the outlet of the Theodore River and approximately 0.2 RKM (0.1 RM) downstream of the Beluga Highway (Figure 1). The location of the weir site was chosen partly due to its close proximity to the road system for timely installation and removal of the weir and logistical support to the field crew.

Lewis River

The Lewis River originates in the Western Foothills of Mount Susitna. The river flows south, approximately 46.7 RKM (29 RM) before entering Cook Inlet. A resistance board weir was installed at lat 61°19′2.96″N, long 150°51′22.14″W, which is approximately 22.5 RKM (14 RM) from the outlet of the Lewis River (Figure 1). In 2014, the weir was relocated approximately 30 meters downstream due to changes in the substrate at the original location. This new location was 0.11 RKM (0.07 RM) from the Beluga Highway. The location of the weir site was chosen partly due to its close proximity to the road system for timely installation and removal of the weir and logistical support to the field crew. No spawning Chinook salmon have been observed below the weir site.

EQUIPMENT, ESCAPEMENT, AND ENUMERATION

Resistance Board Weir

Resistance-board floating weirs were chosen for these sites due to their ability to sink beneath flood waters, allowing debris to pass downstream with little obstruction. Resistance-board weirs require optimal site conditions such as a nearly level bottom profile, substrate that is conducive to anchoring to the stream bed, and low enough water levels during the installation period to allow crew, working in waders or snorkel gear, to attach weir components to the stream bed. Two resistance-board weirs similar to those described in Bartlett (1996) and Tobin (1994) were installed on the Theodore and Lewis rivers (Figure 2). These weirs were operated primarily to count Chinook and coho salmon, but other species of fish were also counted. The space between adjacent pickets on the weir and the live trap were less than or equal to 50 mm (2 in).

High water events can partially submerge the weirs during operation. When the weirs are partially submerged, it is possible for salmon to pass over the weir undetected. Technicians attempted to keep the weirs floating during high water events by removing debris that was submerging the panels. However, when no longer possible, technicians recorded the time and date that the weirs were submerged, and recorded details about how much of the weirs were submerged. When the water stage dropped and the water turbidity decreased enough to positively identify and count salmon, the date and time was recorded and counting was resumed. The weirs were cleaned and inspected daily for holes big enough to allow salmon to pass through the weir undetected.

Escapement

Counts at the weirs were conducted daily, and crews periodically checked and counted the fish in the live trap every couple of hours during daylight to minimize impeding the upstream migration of the salmon. Weir data were recorded on the daily report form (Appendix A1). In addition, daily and cumulative values of salmon counted and sampled were recorded in a waterproof notebook.

Figure 2.–A resistance-board weir installed on the Theodore River in 2014.

BIOLOGICAL SAMPLING

Resistance Board Weir Sampling

Daily sampling at the weirs was conducted during daylight whenever fish were observed in the live box. The following data and samples were collected for Chinook and coho salmon:

1) length measurement from mid eye to tail fork (METF) to the nearest millimeter
2) sex, determined by external characteristics
3) scales sampled to estimate age (Welander 1940; Mosher 1969) independent of size, sex, or other data
4) genetic tissue samples (approximately 2–3 cm of the left axillary process clipped and placed into a bulk container of ethanol to preserve the tissue)

Sampled fish were measured from mid eye to tail fork (METF) to the nearest millimeter. Sex was determined by external physical characteristics, such as kype development (males) or a protruding ovipositor (females). Length and sex were recorded in waterproof notebooks while sampling and later transferred to standard age, weight, and length (AWL) version 1.2 mark-sense forms (G. Heineman, unpublished manual, Instructions for Using Sport Fish Creel Survey and Biological Mark-sense Forms, Alaska Department of Fish and Game, Division of Sport Fish, Anchorage; Appendix A2).

Three scales were taken from each sampled Chinook salmon and a single scale from each sampled coho salmon. All scales were sampled from the preferred location on the left side of the

body at a point on a diagonal line from the posterior insertion of the dorsal fin to the anterior insertion of the anal fin and 2 rows above the lateral line (Appendix B1).

Genetic tissue of Chinook salmon was collected concurrent with ASL collections. For each weir location, bulk tissue containers for Chinook and coho salmon were provided at the beginning of each field season by the Gene Conservation Laboratory. Approximately 2–3 cm of the left axillary process was clipped and placed into a bulk container of ethanol to preserve the tissue.

Chinook Salmon

Because little was known about the run timing of Chinook salmon on the Theodore and Lewis rivers, proportional sampling was used to obtain ASL samples representative of the runs.

In 2012, one ASL sample was taken from every other Theodore River fish and one sample from every Lewis River fish; these sampling frequencies were based upon the required precision criterion (Objective 2) and the mean aerial index count for the last 5 years as an expected run size to each river. The average aerial index counts were 342 Chinook salmon on the Theodore River during 2007–2011 and 95 Chinook salmon on the Lewis River during 2008–2011 (calculated from Table 1).

In 2013–2014, the ASL sampling rate for Chinook salmon was set at 1:3 for the Theodore River and 1:1 for the Lewis River. This sampling scheme was derived using the 2012 runs as the expected run size to each river.

Coho Salmon

Sample sizes for coho salmon age, sex, and length samples were calculated using the procedures outlined by Thompson (1987), adjusting for a finite population and for a nonreadable scale rate of 20%. The sample size required to meet the objective criterion of ±12 percentage points of the true value 95% of the time was 109 fish for the Theodore River and 106 fish for the Lewis River. In 2012 about 140 coho salmon passed through the weir on the Theodore River and 5 coho salmon on the Lewis River by 5 August when the weirs were pulled for the season. Although typical run timing was unknown for the Theodore and Lewis rivers, past Deshka River coho salmon runs have ranged from 89–100% complete by 27 August. In 2012, the first coho salmon at the weir on the Theodore River was observed in the middle of July and on the Lewis River at the end of July. For the sample size calculations, we assumed 4,000 coho salmon as a run size for the Theodore River and 2,000 for the Lewis River (Sam Ivey, Fishery Biologist, ADF&G, Palmer, personal communication).

Proportional sampling was not used; instead, the sample size goal for estimating ASL composition with the specified precision (Objective 5) was set at 50 coho salmon per sample period (7 days) with a total of 8 sample periods over the run yielding 400 samples per year if realized. This strategy was meant to obtain some samples from all portions of the run and would rely on postseason stratification to address bias. In a worst-case scenario, if the entire run passed through the weir in just a couple weeks, we would still be able to achieve stated precision criterion for ASL composition estimates (about 100 fish per river). The 8 sample periods of 7 days each began in mid-July and ended in early September in 2013 and 2014.

RADIOTAGGING THEODORE RIVER CHINOOK SALMON

In 2013, 57 radio tags became available from another project to use in this project. Chinook salmon on the Theodore River were opportunistically tagged with these esophageal radio

transmitters (Advanced Telemetry Systems[1] ATS Model F1845B: 26 grams, 311 day battery life) in order to increase our understanding of Chinook salmon spawning distribution in this system. Transmitters were individually distinguishable by frequency and a unique encoded pulse pattern.

Results from feasibility studies suggest that radiotagging fish less than 400 mm METF length results in a higher probability of stomach rupture (S. Gilk, Fisheries Geneticist, ADF&G, Anchorage, unpublished data). The size and weight of the radio tags may also have more impact on small fish because the radio tag could be about 1.6% of the body weight of a 400 mm METF fish; therefore, fish under 400 mm METF or fish that were obviously injured, spawned out, or appeared stressed, were not radiotagged.

Radio tags were inserted through the esophagus and into the upper stomach using a plastic tube with a diameter smaller than that of the radio tags. To insert a tag, one crew member held the fish in the cradle. The second crew member measured the distance from the tip of the snout to just beyond the posterior base of the pectoral fins in order gauge the proper depth of the tag. The radio transmitter was pushed through the esophagus such that the battery end of the radio tag was seated 0.5 cm beyond the posterior base of the pectoral fin and the antenna protruded out of the fish's mouth. The tagging technician gently tugged on the protruding end of the antenna to ensure the radio tag was securely in place. Implants were performed without the use of anesthesia. All radiotagged Chinook salmon were marked with a uniquely numbered, green anchor tag. This additional tag served as a secondary diagnostic mark for assessing retention of radio transmitters.

Other information collected from radiotagged Chinook salmon included fish color, fish condition, 3 scales for age analysis (Devries and Frie 1996), METF length in millimeters, sex, and 1 axillary process for use in future genetic stock identification analyses independent of this study.

AERIAL SURVEYS AND TRACKING

The aerial escapement index surveys of Chinook salmon were conducted once annually during the peak spawning period in mid to late July in 2012–2014, when water and viewing conditions were acceptable. Each survey was conducted by helicopter from the tidewater confluence upstream to the upper-most reach that Chinook salmon could ascend. Observers wore sunglasses with polarized lenses and attempted to keep the sun behind their shoulders. The chosen air speed and height above the ground varied with light condition and terrain; the aircraft generally flew approximately 50 to 75 feet over the water.

To keep the aerial counts unbiased, weir counts were not known to the observers prior to survey flight. To achieve this, the Anchorage area management biologist (AMB) was the point of contact for the field technicians. The field crew and the Anchorage AMB did not share this information with anyone without the consent of the regional research coordinator (RRC) until after all aerial surveys were conducted.

In 2013, three fixed-wing aerial surveys were conducted on the Theodore River on 20, 26, and 30 July. Radiotelemetry was used to look at the spawning distribution of radiotagged Chinook

[1] Product names used in this publication are included for completeness but to not constitute product endorsement.

salmon. During the aerial radiotelemetry surveys, an ATS radio receiver tracked and recorded GPS coordinates of radiotagged fish.

Each radiotagged Chinook salmon was assigned a frequency and a 3-digit pulse code. The first 2 digits of the pulse code identified the fish and the third digit indicated its behavior (0 indicated the fish was actively migrating, 3 indicated uncertainty as to whether the fish was still active, and 6 indicated a potential mortality).

RIVER TEMPERATURE AND LEVEL

At each weir trap, a protected glass thermometer was attached and submerged in the river at the beginning of the season. The thermometer was pulled out of the river daily at 0900 and 1800 hours; temperature was read to the nearest whole degree Celsius and recorded on the daily report form (Appendix A1).

Water clarity was judged by the technician as excellent, acceptable, or poor each morning at 0900; this observation was recorded on the daily report form. Water level was measured once every morning using a fixed meter stick placed in the rivers and recorded on the daily report form.

DATA ANALYSIS

Age and Sex Composition and Length-at-Age

Chinook Salmon

The age and sex composition of the Chinook salmon escapement was based on proportional sampling at the weirs throughout the run. In 2010, an emergency order closed the Theodore and Lewis rivers to sport fishing, including catch and release, for Chinook salmon. Because no harvest occurred on either river, weir sampling and counts were assumed to be representative of the escapement. The estimated proportion ($\hat{p}_z$) of Chinook salmon of age-sex class z in the escapement (N) was calculated from the sample taken at the mainstem weir (n) using Equation 1:

$$\hat{p}_z = \frac{n_z}{n} \tag{1}$$

where n_z is the number of Chinook salmon out of n sampled that were of age-sex class z, with estimated variance

$$\mathrm{var}(\hat{p}_z) = \left(\frac{N - n}{N}\right)\frac{\hat{p}_z(1-\hat{p}_z)}{n - 1}. \tag{2}$$

When proportional sampling was not achieved, we used poststratification to estimate the age and sex composition of the Chinook salmon escapement. In this case, we split the run into 4 equal time strata and estimated the age-sex composition using the following equations:

$$\hat{p}_{tz} = \frac{n_{tz}}{n_t} \tag{3}$$

where $\hat{p}_{tz}$ equals the estimated proportion of Chinook salmon passing the weir during sampling stratum *t* from age or sex category *z*, n_{tz} equals the number of fish sampled during sampling stratum *t* that were classified as age or sex category *z*, and n_t equals the number of Chinook salmon sampled for age and sex during sampling stratum *t*.

The variance of $\hat{p}_{tz}$ was calculated as follows:

$$\hat{V}[\hat{p}_{tz}] = \left(1 - \frac{n_t}{N_t}\right) \frac{\hat{p}_{tz}(1 - \hat{p}_{tz})}{n_t - 1} \tag{4}$$

where N_t is the number of Chinook salmon passing the weir during sampling stratum *t*.

The total proportion of the escapement by age and sex and its variance were then estimated by the following summations:

$$\hat{p}_z = \sum_{t=1}^{L} \frac{N_t}{N} \hat{p}_{tz} \tag{5}$$

and

$$\hat{V}[\hat{p}_z] = \frac{1}{N^2} \sum_{t=1}^{L} N_t^2 \hat{V}[\hat{p}_{tz}] \tag{6}$$

where $L = 4$ is the number of temporal strata and N_t/N are the stratum weights.

Coho Salmon

The estimated age and sex composition of the coho salmon escapement was based on samples collected at the mainstem weirs. The estimated proportion ($\hat{p}_z$) of coho salmon of age-sex class *z* in the escapement (*N*) and its variance ($\hat{V}[\hat{p}_z]$) were calculated using poststratification Equations 3–6.

Mean Length-by-Sex

For both Chinook and coho salmon, mean length-by-sex class *z* was estimated as follows:

$$\bar{l}_z = \frac{1}{n_z} \sum_{i=1}^{n_z} l_i \tag{7}$$

where

l_i = the length of fish *i* in a sample n_z and

n_z = the number of Chinook (or coho) salmon of sex class *z*.

The variance of the mean length-by-sex class *z* was estimated by

$$\text{var}(\bar{l}_z) = \frac{1}{n_z} \frac{\sum_{i=1}^{n_z} (l_i - \bar{l}_z)^2}{n_z - 1}. \tag{8}$$

RESULTS

OPERATION DATES

Theodore River Weir

In 2012, the Theodore River weir was installed on 1 June and operated until 5 August. In 2013, the weir was installed on 1 June, with operations extended until 5 September to determine the escapement of coho salmon. In 2014, the weir was installed on 21 May and operated until 11 July.

Lewis River Weir

In 2012, the Lewis River weir was installed on 30 May and operated until 3 August. In 2013, the weir was installed on 30 May, with operations extended until 5 September to determine the escapement of coho salmon. In 2014, the weir was installed on 23 May and operated until 20 July.

CHINOOK SALMON

Escapement and Run Timing

Theodore River

In 2012, an aerial index survey conducted on 18 July observed a total of 179 Chinook salmon for the entire Theodore River. Of the 179 observed, 129 were counted upstream of the weir. At the time of the index survey, 577 Chinook salmon had passed upstream of the weir site (Table 3).

In 2013, an aerial index survey conducted on 18 July observed a total of 476 Chinook salmon for the entire Theodore River. Of the 476 observed, 434 were counted upstream of the weir. At the time of the index survey, 630 Chinook salmon had passed upstream of the weir site (Table 3).

In 2014, an aerial index survey conducted on 20 July observed a total of 312 Chinook salmon for the entire Theodore River. All 312 were counted upstream of the weir. At the time of the index survey, 198 Chinook salmon had passed upstream of the weir site (Table 3). However, an accurate weir count of Chinook salmon escapement on the Theodore River in 2014 was not possible due to a shortened weir season (operation ended on 11 July) in addition to multiple high water events, which accounted for more than 25% of the time the weir was operational. In 2014, the Theodore River weir did not operate on 30 May–3 June, 26 June–1 July, and 10–11 July.

The mean Chinook salmon aerial index count for 2012–2014 for the Theodore River was 322 fish. Accumulated weir counts on the index count date for the Theodore River averaged 468 Chinook salmon over the 2012–2014 seasons. The 2012 and 2013 final weir counts were similar, with 657 and 684 fish, respectively. For reasons mentioned above, the 2014 final weir count was only 198 Chinook salmon.

Table 3.–Comparison of aerial index to weir counts for the Theodore and Lewis rivers in 2012–2014.

Year	River	Date of index survey	Total index count	Index upstream of weir	Cumulative weir count on survey date	Final weir count	Index/weir
2012							
	Theodore	18 Jul	179	129	577	657	22%
	Lewis	18 Jul	107	28	58	111	48%
2013							
	Theodore	18 Jul	476	434	630	684	69%
	Lewis	18 Jul	61	57	0	3	[a]
2014							
	Theodore	20 Jul	312	312	198	198	[b]
	Lewis	20 Jul	61	61	7	7	[b]

[a] Lewis River jumped its bank prior to season, which probably allowed fish passage in an old channel during high spring runoff and prior to weir installation.

[b] Weir count was incomplete due to multiple high water events.

Based on the 1 June–5 August weir count, the midpoint of the 2012 Chinook salmon run was reached on 19 June; the first salmon was counted through the weir on 2 June and the last on 3 August. The highest daily count (111 Chinook salmon) was recorded on 19 June (Figure 3). Based on the 1 June–5 September weir count, the midpoint of the 2013 run was reached on 24 June; the first Chinook salmon arrived on 6 June and the last on 18 August. The highest daily passage occurred on 7 July, when 78 salmon passed through the weir. The weir was installed at its earliest date in 2014 (21 May) and recorded the first Chinook salmon passage on 24 May. The midpoint of the 2014 Chinook salmon run was reached on 14 June, although the run count cannot be considered complete because the final fish was counted on 22 June and after a high water event, the weir was washed downstream on 11 July, ending field operations for the season. The highest daily passage (30 Chinook salmon) was on 13 June.

Lewis River

In 2012, an aerial index survey conducted on 18 July observed a total of 107 Chinook salmon in the Lewis River. Of the 107 observed, 28 were counted upstream of the weir. At the time of the index survey, 58 Chinook salmon had passed upstream of the weir site (Table 3).

In 2013, an aerial index survey conducted on 18 July observed a total of 61 Chinook salmon in the Lewis River. Of the 61 observed, 57 were counted upstream of the weir. At the time of the index survey, zero Chinook salmon had passed upstream of the weir site (Table 3). Rerouting of the main river channel during a part of the migration season prevented Chinook salmon from passing upstream of the weir and thus prevented obtaining an accurate count of the Chinook salmon escapement on the Lewis River in 2013.

In 2014, an aerial index survey conducted on 20 July observed a total of 61 Chinook salmon in the Lewis River. All 61 observed were counted upstream of the weir. At the time of the survey, 7 Chinook salmon had passed upstream of the weir site (Table 3). However, an accurate weir count of Chinook salmon escapement on the Lewis River in 2014 was not possible due to a shortened weir season (operation ended on 20 July) in addition to multiple high water events, which accounted for 27% of the time the weir was operational. These high water events prevented the Lewis River weir from being operational on 30 May–4 June, 26 June–1 July, and 10–13 July.

The average Chinook salmon index count for 2012–2014 for the Lewis River was 76 fish. The average final weir count for 2012–2014 for Chinook salmon passing the Lewis River weir was 40 salmon, although weir counts were incomplete in 2013 and 2014. The greatest number of Chinook salmon passed the weir in 2012 (111 fish) whereas only 3 and 7 fish passed the weir in 2013 and 2014, respectively (Table 3).

Based on 30 May–3 August weir counts, the midpoint of the 2012 Lewis River Chinook salmon run was reached on 16 July; the first fish was counted on 17 June and the last fish was counted on 2 August. The highest daily passage (23 fish) occurred on 15 July (Figure 4). Based on 30 May–5 September weir counts, the midpoint of the 2013 Chinook salmon run was reached on 14 August, but note that this count is incomplete because of a rerouted river channel. A total of only 3 Chinook salmon passed through the weir during 2013; the first was on 11 August, the second was on 14 August, and the last was on 18 August. As in 2013, few Chinook salmon passed through the Lewis River weir in 2014. Based on 23 May–20 July weir counts, 7 fish were counted: the first on 19 June and the last on 22 June. The highest daily count and midpoint of the (incomplete) run both occurred on 19 June, though the weir was pulled on 20 July.

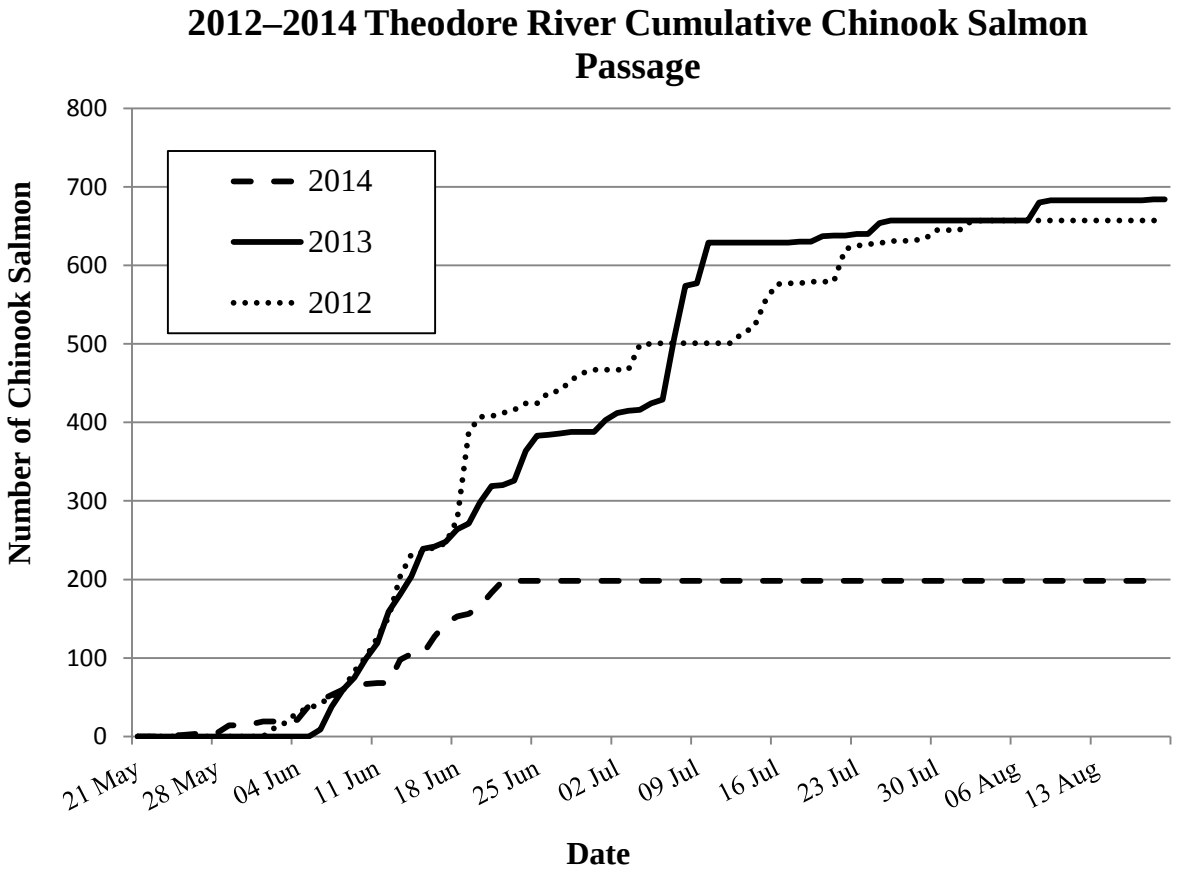

Figure 3.–Cumulative number by date of Chinook salmon passing the Theodore River weir, 2012–2014.

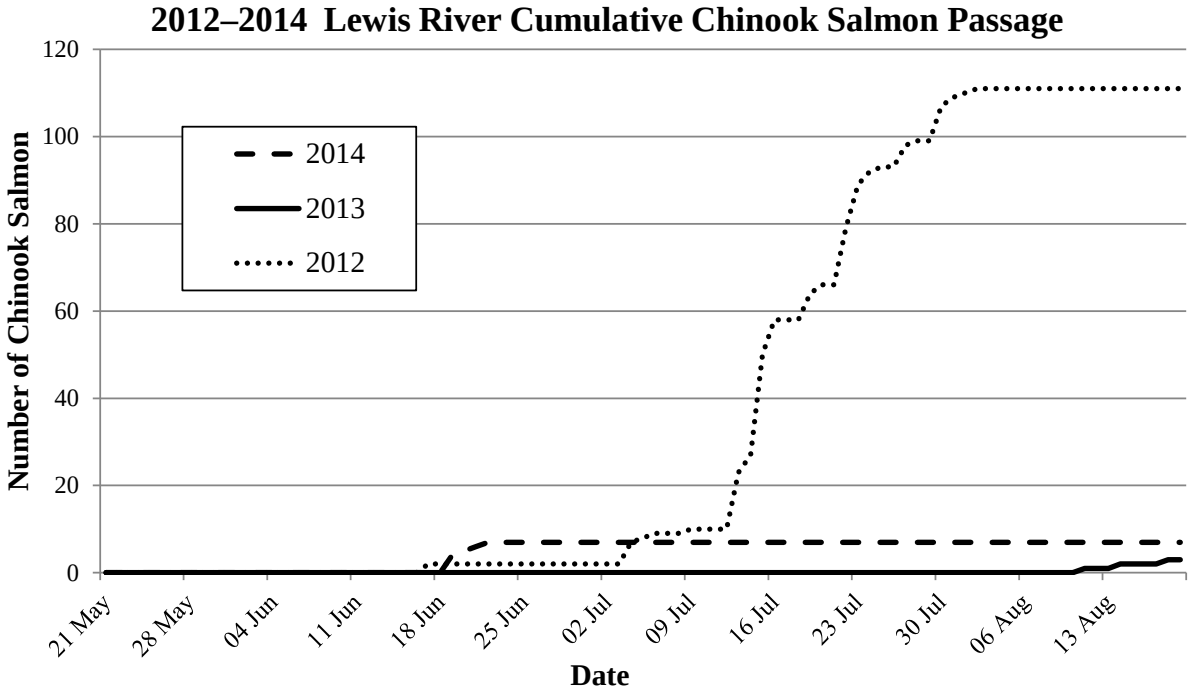

Figure 4.–Cumulative number by date of Chinook salmon passing the Lewis River weir, 2012–2014.

Theodore River Spawning Distribution

We expected the run in 2013 to be similar to 2012; therefore, based on the 2012 run timing, tags were to be deployed proportionally throughout the first 577 fish. With 57 tags to deploy, we attempted to tag every 10th fish. This strategy worked well with the ASL and genetic sampling rate of every third fish that was already going on at the site concurrently.

At the Theodore River weir site in 2013, 47 radio tags were deployed in Chinook salmon proportionally throughout the run (Appendix C1) in fish that would be above the weir at the time of the aerial index survey. The 2012 weir count (657 Chinook salmon) was used to deploy tags in this manner. Three aerial radiotracking surveys were conducted on the Theodore River on 20, 26, and 30 July to document spawning distribution and the maximum upstream extent that radiotagged Chinook salmon were located (Figure 5). Of the 47 tags deployed, 16 (34%) transmitted mortality code 6. Mortality codes documented on the radiotelemetry aerial surveys could be attributed to handling, bear predation, or regurgitation of the tag but not mortalities associated with spawning because radiotagged Chinook salmon were surveyed prior to the time when spawning mortality occurs. Final locations of radiotagged Chinook salmon and putative spawning areas were evenly distributed throughout the Theodore River. The furthest upstream radiotagged Chinook salmon was documented at approximately RM 32, which is approximately 25 RM upstream from the tag site (weir).

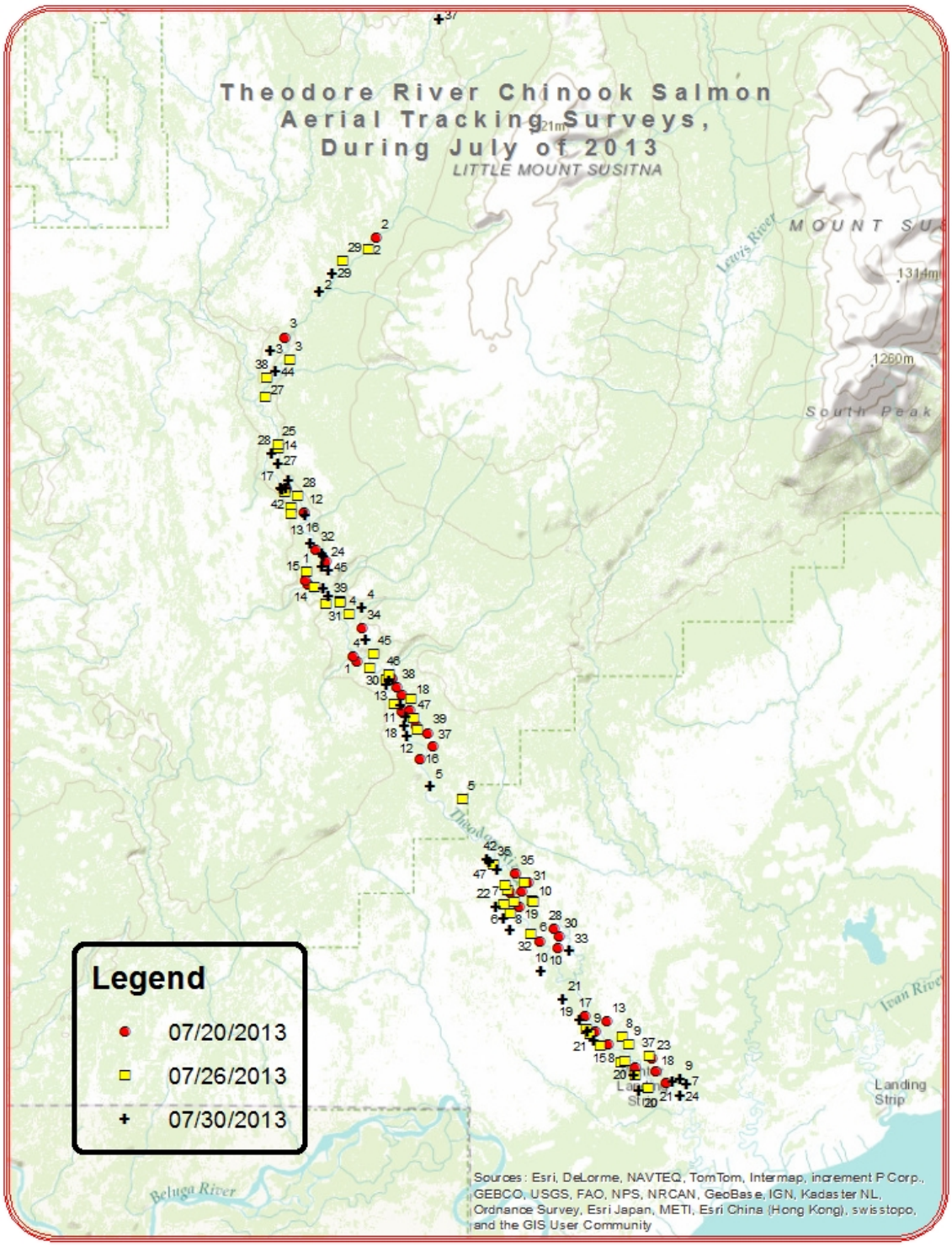

Figure 5.–Theodore River Chinook salmon spawning distribution from aerial tracking surveys of 47 radiotagged fish, July 2013.

COHO SALMON

Escapement and Run Timing

Theodore River

In 2013, a total of 1,560 coho salmon passed through the weir between 20 July and 31 August (Figure 6). The midpoint of the 2013 coho salmon run was reached on 9 August. The highest daily passage occurred on 9 August, when 474 coho salmon passed through the weir. In 2014, several high water events and damage to the weir caused the Theodore River weir to be inoperable as of 11 July for the remainder of the season and precluded enumeration of the coho salmon run for 2014.

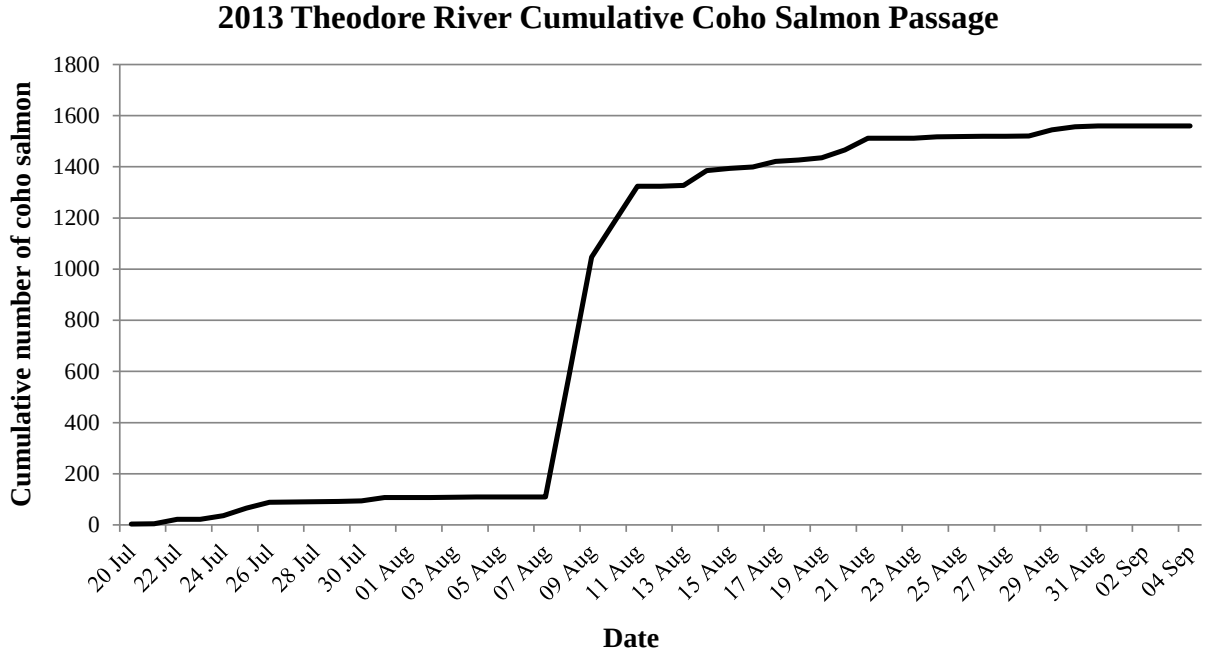

Figure 6.–Cumulative number by date of coho salmon passing the Theodore River weir, 2013.

Lewis River

In 2013, 413 coho salmon passed through the weir between 30 July and 31 August (Figure 7). The midpoint of the 2013 coho salmon run was reached on 13 August. The highest daily passage took place on 13 August, when 60 coho salmon passed the weir. Enumeration of coho salmon in the Lewis River was set to occur during the 2014 season, but was prevented due to early termination of the field season, which was concluded on 20 July.

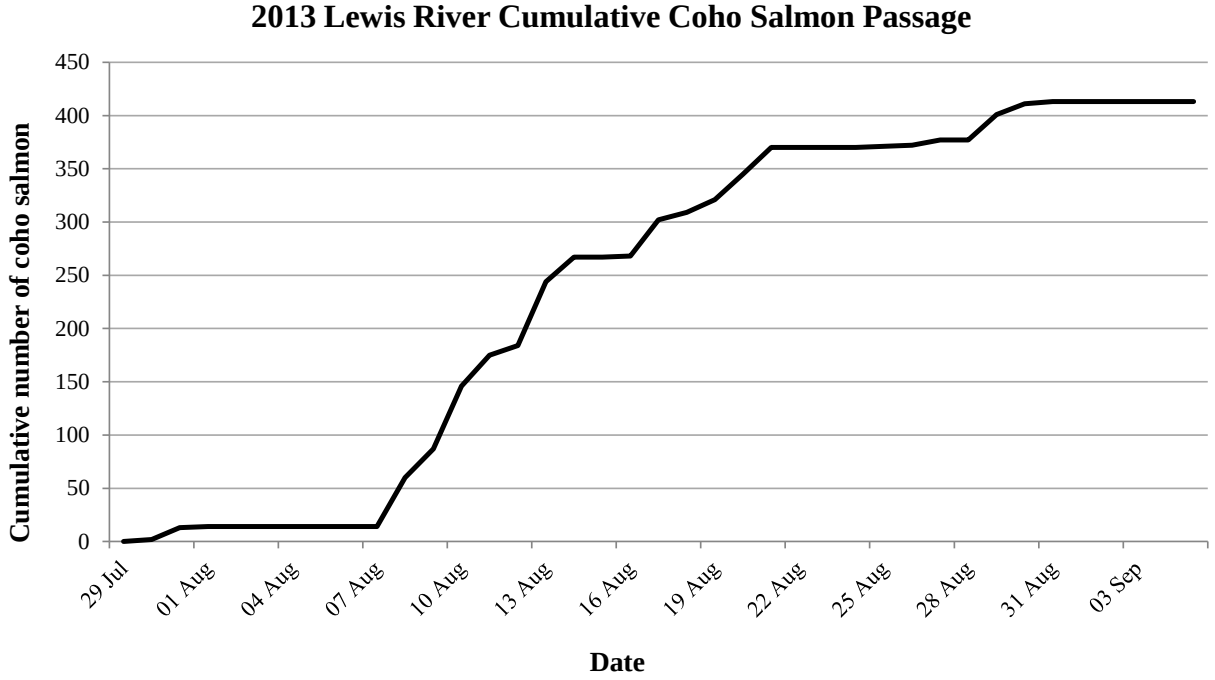

Figure 7.–Cumulative number by date of coho salmon passing the Lewis River weir, 2013.

BIOLOGICAL SAMPLING

Chinook Salmon

Theodore River

In 2012, a total of 316 Chinook salmon were sampled for age, sex, and length at the Theodore River weir. Proportional sampling was not achieved in 2012. Of the 316 Chinook salmon sampled, 245 (77.5%, SE 1.7%) were male and 71 (22.5%, SE 1.7%) were female. Lengths of sampled males ranged between 377 mm and 980 mm, with a mean length of 600 mm (SE 6 mm). Lengths of sampled females ranged between 504 mm and 999 mm, with a mean length of 771 mm (SE 11 mm) (Table 4). Of the 316 Chinook salmon sampled at the Theodore River weir, 247 (78%) had scales that could be aged. The dominant age class in the 2012 was ocean age 2, representing 65.6% (SE 2.4%) of the Chinook salmon escapement. There were 27.1% (SE 2.2%) ocean-age-3 fish and 7.3% (SE 1.3%) ocean-age-4 fish.

In 2013, a total of 252 Chinook salmon were sampled for age, sex, and length at the Theodore River weir. Proportional sampling was not achieved in 2013. Of the 252 Chinook salmon sampled, 159 (63.1%, SE 2.4%) were male and 93 (36.9%, SE 2.4%) were female. Lengths of sampled males ranged between 413 mm and 1,050 mm, with a mean length of 680 mm (SE 10 mm). Lengths of sampled females ranged between 588 mm and 943 mm, with a mean length of 792 mm (SE 6 mm) (Table 4). Of the 252 Chinook salmon sampled at the Theodore River weir, 192 (76%) had scales that could be aged. The dominant age class for 2013 was ocean age 3, representing 57.6% (SE 3.3%) of the Chinook salmon escapement. There were 32.6% (SE 3.1%) ocean-age-2 fish and 9.8% (SE 2.2%) ocean-age-4 fish.

In 2014, a total of 67 Chinook salmon were sampled for age, sex, and length at the Theodore River weir. Proportional sampling was not achieved in 2014. Of the 67 sampled Chinook salmon, 30 (44.8%, SE 6.1%) were male and 37 (55.2%, SE 6.1%) were female. Lengths of sampled males ranged between 293 mm and 980 mm, with a mean length of 481 mm (SE 41 mm). Lengths of sampled females ranged between 358 mm and 891 mm, with a mean length of 620 mm (SE 26 mm) (Table 4). Of the 67 Chinook salmon sampled at the Theodore River weir, 29 (43%) had scales that could be aged. The dominant age class for 2014 was ocean age 3, representing 41.4% (SE 9.3%) of the Chinook salmon escapement. There were 24.1% (SE 8.1%) ocean-age-4 fish, 20.7% (SE 7.7%) ocean-age-1 fish, and 13.8% (SE 6.5%) ocean-age-2 fish. All of the age estimates were probably biased because a large but unknown portion of the run was not accounted for or sampled due to multiple high water events at the weir.

Overall, a total of 635 Chinook salmon were sampled on the Theodore River. Of the 635 Chinook salmon sampled, 434 (68.3%) were male and 201 (31.7%) were female. Lengths of sampled males ranged between 293 mm and 1,050 mm, with a mean length of 622 mm (SE 5.6 mm). Lengths of sampled females ranged between 358 mm and 999 mm, with a mean length of 753 mm (SE 6.8 mm). Of the 635 Chinook salmon sampled at the weir, 468 (74%) had scales that could be aged. The overall dominant age class was ocean age 2, representing 48.7% of the escapements. There were 41.5% ocean-age-3 fish, 8.5% ocean-age-4 fish, and 1.3% ocean-age-1 fish.

Table 4.–Theodore River weir Chinook salmon escapement sex composition and mean length, 2012–2014.

Year	Parameter	Male	Female	Total
2012				
	n	245	71	316
	% (*n*)	77.5	22.5	
	SE (% *n*)	1.7	1.7	
	Mean length (mm)	600	771	
	SE (length)	6	11	
	Range (length)	377–980	504–999	
	n (length)	240	70	
2013				
	n	159	93	252
	% (*n*)	63.1	36.9	
	SE (% *n*)	2.4	2.4	
	Mean length (mm)	680	792	
	SE (length)	10	6	
	Range (length)	413–1,050	588–943	
	n (length)	151	89	
2014				
	n	30	37	67
	% (*n*)	44.8	55.2	
	SE (% *n*)	6.1	6.1	
	Mean length (mm)	481	620	
	SE (length)	41	26	
	Range (length)	293–980	358–891	
	n (length)	25	37	

Lewis River

In 2012, a total of 87 Chinook salmon were sampled for sex and length at the Lewis River weir. Proportional sampling was not achieved in 2012. Of the 87 Chinook salmon sampled, 67 (78.1%, SE 2.4%) were male and 20 (21.9%, SE 2.4%) were female. Lengths of sampled males ranged between 505 mm and 982 mm, with a mean length of 667 mm (SE 15 mm). Lengths of sampled females ranged between 579 mm and 977 mm, with a mean length of 821 mm (SE 27 mm) (Table 5). Of the 87 sampled Chinook salmon, 71 (82%) had scales that could be aged. The dominant age class for 2012 was ocean age 2, representing 65.4% (SE 4.0%) of the Chinook salmon escapement. There were 24.1% (SE 3.8%) ocean-age-3 fish, 8.9% (SE 1.8%) ocean-age-4 fish, and 1.6% (SE 1.1%) ocean-age-1 fish.

In 2013, no Chinook salmon were sampled.

In 2014, a total of 7 Chinook salmon were sampled for sex and length at the Lewis River weir. Of the Chinook salmon sampled, 1 (14.3%, SE 14.3%) was male and 6 (85.7%, SE 14.3%) were female. Lengths of sampled females ranged between 570 mm and 960 mm with a mean length of 786 mm (SE 55mm) (Table 5). All (100%) of the Chinook salmon sampled at the Lewis River had scales that could be aged. The dominant age class for 2014 was ocean age 3, representing 57.1% (SE 20.2%) of the Chinook salmon escapement. There were 42.9% (SE 20.2%) ocean-age-4 fish. However, these estimates were probably biased because a large but unknown portion of the run was not accounted for or sampled due to multiple high water events at the weir.

Overall, a total of 94 Chinook salmon were sampled on the Lewis River. Of the 94 Chinook salmon sampled, 68 (72%) were male and 26 (28%) were female. Lengths of sampled males ranged between 505 mm and 982 mm, with a mean length of 669 mm (SE 14.8 mm). Lengths of sampled females ranged between 570 mm and 977 mm, with a mean length of 813 mm (SE 24.3 mm). Of the 94 Chinook salmon sampled, 78 (83%) had scales that could be aged. The dominant age class was ocean age 2, representing 57.7% of the Chinook salmon escapement. There were 28.2% ocean-age-3 fish, 12.8% ocean-age-4 fish, and 1.3% ocean-age-1 fish.

Table 5.–Lewis River weir Chinook salmon escapement sex composition and mean length, 2012 and 2014.

Year	Parameter	Male	Female	Total
2012				
	n	67	20	87
	% (*n*)	78.1	21.9	
	SE (% *n*)	2.4	2.4	
	Mean length (mm)	667	821	
	SE (length)	15	27	
	Range (length)	505–982	579–977	
	n (length)	64	20	
2014				
	n	1	6	7
	% (*n*)	14.3	85.7	
	SE (% *n*)	14.3	14.3	
	Mean length (mm)	790	786	
	SE (length)	–	55	
	Range (length)	–	570–960	
	n (length)	1	6	

Coho Salmon

Theodore River

In 2013, a total of 186 coho salmon were sampled for sex and length at the Theodore River weir. Of the 186 coho salmon sampled, 126 (63.9%, SE 3.8%) were male and 60 (36.1%, SE 3.8%) were female. Lengths of sampled males ranged between 465 mm and 662 mm, with a mean length of 554 mm (SE 4mm). Lengths of sampled females ranged between 486 mm and 627 mm, with a mean length of 549 mm (SE 3 mm) (Table 6). Of the 186 coho salmon sampled at the Theodore River, 67 (36%) had scales that could be aged. The dominant age class in 2013 was ocean age 2, representing 84.3% (SE 4.8%) of the coho salmon escapement. There were 14.9% (SE 4.8%) ocean-age-3 fish.

Table 6.–Theodore River weir coho salmon escapement sex composition and mean length, 2013.

Year	Parameter	Male	Female	Total
2013				
	n	126	60	186
	% (*n*)	63.9	36.1	
	SE (% *n*)	3.8	3.8	
	Mean length (mm)	554	549	
	SE (length)	4	3	
	Range (length)	465–662	486–627	
	n (length)	123	58	

Lewis River

In 2013, a total of 172 coho salmon were sampled for sex and length at the Lewis River weir. Of the 172 coho salmon sampled, 119 (69.2%, SE 2.7%) were male and 53 (30.8%, SE 2.7%) were female. Lengths of sampled males ranged between 415 mm and 626 mm, with a mean length of 543 mm (SE 3 mm). Lengths of sampled females ranged between 421 mm and 574 mm, with a mean length of 536 mm (SE 4 mm) (Table 7). Of the 172 coho salmon sampled at the Lewis River weir, 68 (40%) had scales that could be aged. The dominant age class in 2013 was ocean age 2, representing 89.7% (SE 3.5%) of the coho salmon escapement. There were 6.1% (SE 2.8%) ocean-age-3 fish and 4.2% (SE 2.2%) ocean-age-1 fish.

Table 7.–Lewis River weir coho salmon escapement sex composition and mean length, 2013.

Year	Parameter	Male	Female	Total
2013				
	n	119	53	172
	% (*n*)	69.2	30.8	
	SE (% *n*)	2.7	2.7	
	Mean length (mm)	543	536	
	SE (length)	3	4	
	Range (length)	415–626	421–574	
	n (length)	115	53	

DISCUSSION

The Theodore and Lewis River weirs were part of a 3-year project (2012–2014) originally adopted to enumerate the inriver escapement of Chinook salmon in order to assess the reliability of the aerial escapement index surveys usually conducted on these systems for management purposes. Original funding through AKSSF only allowed these weirs to operate through the end of the Chinook salmon runs. Additional funding was supplemented (State General Fund) in order to extend the weir's operation through the fall to enumerate coho salmon escapements for the 2013 and 2014 runs.

The Theodore and Lewis rivers proved to be difficult systems to monitor using resistance board weirs. Fine and loose substrate, combined with drainage characteristics that allow water levels to go up and down extremely quickly caused numerous inoperable periods during this project. These conditions quickly eroded sections under the weir's rail, allowing fish to pass undetected while reducing the structural integrity of the weirs themselves. This was a chronic problem at both the Theodore River and Lewis River weirs, and combined with the relatively short and condensed runs of both the Chinook and coho salmon stocks, there is increased potential to miss substantial portions of these runs. This was evident in 2013 and 2014 in the Lewis River, where 61 Chinook salmon were counted above the weir during the aerial index survey in both years, whereas only 3 (2013) and 7 (2014) of those fish were counted passing the weir during operational periods up to the survey dates.

Proportional sampling for age and sex composition of Chinook salmon runs was not achieved during this project on both rivers. We used a poststratification technique to estimate age and sex composition of the Chinook salmon escapement. It is worth noting that stratified estimates of the age and sex composition were very close to the unstratified estimates (within 1–2%) in all instances. The reason for this is that the age and sex proportions were relatively similar throughout the duration of the Chinook salmon runs within years.

THEODORE RIVER CHINOOK SALMON

In 2012 and 2013, the Theodore River weir was effective in providing a reliable Chinook salmon escapement count to compare to the aerial escapement surveys (Table 3). In 2012, there were no inoperable days to due to high water; a single aerial escapement survey conducted on 18 July accounted for 129 (22%) of the 577 Chinook salmon that had passed above the weir at the time of the survey. In 2013, there were 13 inoperable days due to high water; the first high water event took place on 5 August. However, based on the 2012 daily counts (Figure 3), nearly all Chinook salmon (~95%) had passed the weir prior to 3 August. The aerial escapement survey conducted on 18 July accounted for 434 (69%) of the 630 Chinook salmon that had passed above the weir at the time of the survey in 2013. In 2014, multiple high water events resulted in a substantial amount of Chinook salmon passing through the weir undetected. The aerial index survey counted a total of 312 Chinook salmon above the weir, whereas only 198 had been counted passing above weir at the time of the survey. Many high water events in 2014 during substantial portions of the migration season and a lack of historical data for both the Theodore and Lewis river systems made the meaningful use of statistical methods to fill in the missing counts impossible.

Aerial escapement estimates on the Theodore River in 2012 and 2013 were comparable to Southeast Alaska expansion factors. Pahlke (2010) estimated peak aerial survey to weir

escapement expansion factors ranging from 1.52 to 5.36 for Chinook salmon escapements in transboundary rivers in Southeast Alaska, indicating that the average percentage of salmon observed in aerial surveys can range from 66% (King Salmon River) to 19% (Stikine River). The variability and accuracy may vary greatly from year to year. Changes in migratory timing, inclement weather, turbidity events, or changes in pilot or observer are contributing factors.

The Theodore River has shown a general decline in Chinook salmon run strength over the previous 35 years of aerial index surveys (Table 1). The mean Chinook salmon escapement for 2012–2014, as observed by the aerial survey method, was 322 fish. This total was substantially less than the 35-year mean of 917 (Table 1). The Theodore River weir observed a season average of 468 Chinook salmon on the index survey date from 2012 to 2014. The 2012 and 2013 season totals were similar, at 657 fish in 2012 and 684 in 2013. There were 198 Chinook salmon observed passing the weir in 2014, but the weir was operated for a shorter period and there were several inoperable periods due to high water on 30 May–3 June, 26 June–1 July, and 10–11 July. According to informal staff reports, a substantial number of Chinook salmon probably passed the weir without being counted; evidence of this is corroborated by a higher aerial survey count compared to weir escapement (Table 3).

At the Theodore River weir site in 2013, 47 radio tags were deployed in Chinook salmon proportionally throughout the run (Appendix C1) in fish that would be above the weir at the time of the aerial index survey. Final locations of radiotagged Chinook salmon and putative spawning areas were evenly distributed throughout the Theodore River (Figure 5). The farthest upstream radiotagged Chinook salmon was documented at approximately RM 32, which is approximately 25 RM upstream from the tag site (weir).

With only 3 years of weir escapement data and inconsistent counts due to high water, assessing whether aerial surveys provide a reliable index of Chinook salmon escapement on the Theodore River was not possible with weir data. Given difficulties with the weir, the aerial index surveys, which have been conducted annually since 1979, remain the most effective way to assess escapement and manage the Chinook salmon fishery on the Theodore River.

LEWIS RIVER CHINOOK SALMON

In 2012, the Lewis River weir was effective in providing a reliable Chinook salmon escapement count to compare to the aerial escapement survey (Table 3). There were no inoperable days due to high water, and the aerial escapement surveys accounted for 28 (48%) of the 58 Chinook salmon that had passed above the weir at the time of the survey. In 2013, the aerial index survey counted a total of 61 Chinook salmon above the weir; at the time of the survey however, zero Chinook salmon had been observed passing the weir. During the 18 July aerial Chinook salmon survey, the surveyor noticed that the river had rerouted down an old channel that led to swampy flats approximately 1 mile downstream of the weir site. This rerouting caused the existing main channel to dry up completely below the weir, preventing returning salmon from navigating up the Lewis River. The 61 Chinook salmon counted above the weir probably passed prior to weir installation. Eventually, the river resumed its normal course and on 30 July, the first counted fish of the season passed the weir site. In 2014, multiple high water events resulted in a substantial amount of Chinook salmon passing through the weir undetected. The aerial index survey counted a total of 61 Chinook salmon above the weir whereas only 7 had passed above weir at the time of the survey. As a result of these issues, 2013 and 2014 Chinook salmon weir counts on the Lewis River are considered incomplete.

Aerial escapement estimates on the Lewis River in 2012 were comparable to Southeast Alaska expansion factors Pahlke (2010). Chinook salmon escapement, as measured by the aerial index survey, has declined in the Lewis River since 1979. The mean run strength (recorded by aerial survey) from 2012 to 2014 was 76 fish. This is less than the 10-year mean of 139 fish (2005–2014) and substantially less than the 35-year mean of 441 fish (Table 1).

The 2012 season was the only year with reliable Chinook salmon weir observations. There were 111 fish counted in 2012, whereas 2013 and 2014 counts totaled just 3 and 7 fish, respectively during operational periods when high water did not preclude fish observations.

With only 3 years of weir escapement data and inconsistent counts due to high water, assessing whether aerial surveys provide a reliable index of Chinook escapement on the Lewis River is not possible. Given difficulties with the weir, aerial index surveys, which have been conducted annually since 1979, remain the most effective way to monitor escapement and manage the Chinook salmon fishery on the Lewis River.

COHO SALMON

The objective of additional funding was to extend the weir counts on the Theodore and Lewis rivers to estimate coho salmon escapements in 2013 and 2014 (coho salmon harvest from sport fishing above and below the weir may affect differences between estimated and true escapements). On the Theodore River in 2013, a total of 1,560 coho salmon passed through the weir between 20 July and 31 August (Figure 6). The midpoint of the 2013 coho salmon run was reached on 9 August. The highest daily passage occurred on 9 August, when 474 coho salmon passed through the weir. This is considered a complete run count. In 2014, several high water events and damage to the weir caused the Theodore River weir to be inoperable. On the morning of 11 July, swift water had eroded substrate under the rail of the Theodore River weir, and when a root wad impacted and severely damaged the tripod on the right bank, the weir was washed downstream, causing significant damage to the weir. The decision to remove the weir on the Theodore River in 2014 was made on 21 July for the following reasons: 1) the earliest estimate that the weir could be redeployed under ideal conditions was 1 August, 2) based on the only year of complete coho salmon weir counts on the Theodore River (2013), it is likely that a substantial portion of the coho salmon escapement would have been missed by the time the weir was reinstalled, 3) with only 1 prior year of coho salmon counts, it would not have been possible to accurately estimate the missed passage of the coho salmon run, and therefore an estimate of total escapement for the season could not be produced, and 4) any information gathered from the weir, if it had been reinstalled would probably have been of little value due to the incomplete survey of coho salmon abundance.

On the Lewis River in 2013, 413 coho salmon passed through the weir between 30 July and 31 August (Figure 7). The midpoint of the 2013 coho salmon run was reached on 13 August. The highest daily passage took place on 13 August when 60 coho salmon passed through the weir. This is considered a complete count of the run. In 2014, enumeration of coho salmon in the Lewis River was prevented due to early termination of the field season, which was concluded on 20 July, before the start of the coho salmon run. The Lewis River weir was removed in conjunction with Theodore River weir for the following reasons: 1) the Lewis River hosts a very small run of coho salmon (2013 operations estimated 413 coho salmon past the weir), 2) typical fall water conditions would probably result in additional inoperable periods, further negatively affecting our ability to estimate 2014 coho salmon escapement, 3) staff assigned to the project

(a Fish and Wildlife Technician II, a Fish and Wildlife Technician III, and a Fishery Biologist I) were better utilized in other regional coho salmon research projects where staff were already spread thin, and 4) this was not a long-term project and 2014 was its final season based upon existing funding.

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REFERENCES CITED

Alaska Department of Fish and Game. 1995. Report on implementation of the 1992 subsistence law. Alaska Department of Fish and Game, Special Publication No. SP1995-001, Anchorage.

Bartlett, L. D. 1996. Escapement and stock statistics for Coho salmon on the Little Susitna River and selected Matanuska-Susitna Valley, Alaska streams during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 96-16, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/fds96-16.pdf

Cook Inlet Staff. 2011. Chuitna River, Theodore River, and Lewis River King Salmon Stock Status and Action Plan,2011. Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game Divisions of Sport Fish, Commercial Fisheries, and Subsistence. http://www.adfg.alaska.gov/static-f/regulations/regprocess/fisheriesboard/pdfs/2010_2011/uci/wci-chinook.pdf

Devries, D. R., and R. V. Frie. 1996. Determination of age and growth. Pages 485-513 [*In*] B. Murphy and D. Willis, editors. Fisheries Techniques. American Fisheries Society, Bethesda.

Ivey, S., C. Brockman, and D. Rutz. 2007. Overview of the northern Cook Inlet area sport fisheries with proposals under consideration by the Alaska Board of Fisheries, February, 2008. Alaska Department of Fish and Game, Fishery Management Report No. 07-65, Anchorage. http://www.adfg.alaska.gov/FedAidPDFs/FMR07-65.pdf

Mosher, K. H. 1969. Identification of Pacific salmon and steelhead trout by scale characteristics. U. S. Fish and Wildlife Service, Bureau of Commercial Fisheries, Circular 317.

Oslund, S., S. Ivey, and D. Lescanec. 2013. Area Management Report for the recreational fisheries of Northern Cook Inlet, 2011-2012. Alaska Department of Fish and Game, Fishery Management Report No. 13-50, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/FMR13-50

Pahlke, K. A. 2010. Escapements of Chinook salmon in Southeast Alaska and transboundary rivers in 2008. Alaska Department of Fish and Game, Fishery Data Series No. 10-71, Anchorage. http://www.adfg.alaska.gov/FedAidpdfs/fds10-71.pdf

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. The American Statistician 41(1):42-46.

Tobin, J. H. 1994. Construction and performance of a portable resistance board weir for counting migrating adult salmon in rivers. U.S. Fish and Wildlife Service, Kenai Fishery Resource Office, Alaska Fisheries Technical Report Number 22, Kenai.

Welander, A. D. 1940. A study of the development of the scale of Chinook salmon Oncorhynchus tshawytscha. Master's thesis. University of Washington, Seattle.

APPENDIX A: REPORT FORMS

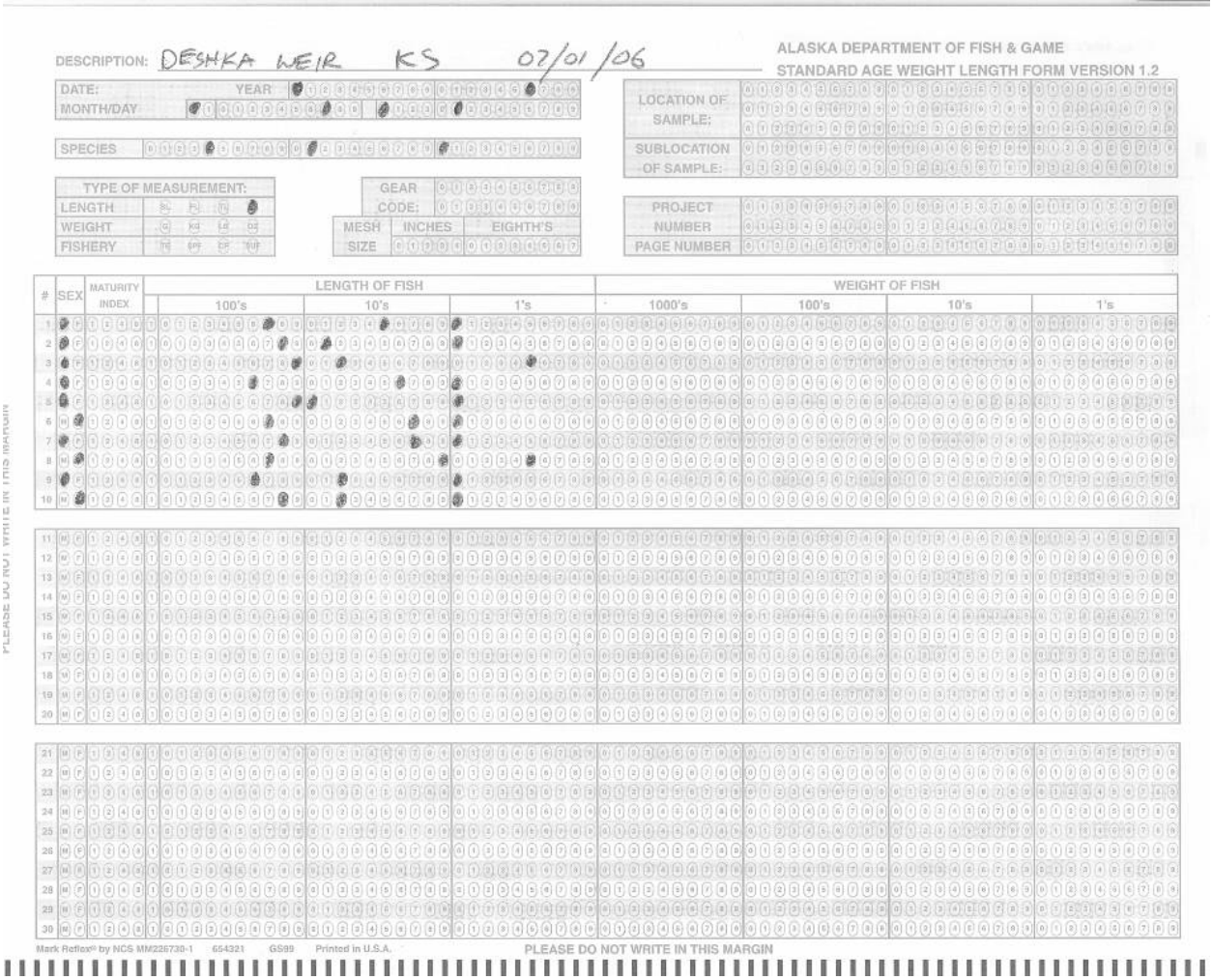
Appendix A1.–Daily report form for counts of fish passing through the Theodore River and Lewis River weirs.

Theodore / Lewis Weir, Daily Report Form

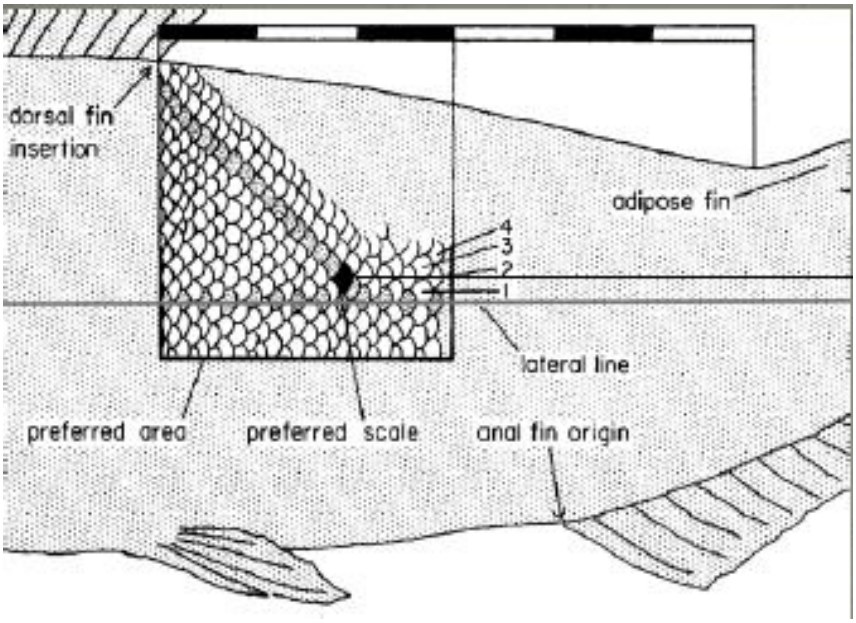
Page:___ Of:___

Date	**Chinook Salmon**				Coho	Sock.	Pink	Chum	Dolly	Other	Stream Conditions, Etc.			Notes
	Count	Sampled	M/F	Cummulative	Count	Count	Count	Count	Count	Count	Stg.	Temp AM/PM	Clarity	

Appendix A2.–An example of the standard age, sex, length mark-sense form used for the Theodore River and Lewis River weirs.



APPENDIX B: SCALE AGE SAMPLING



Appendix B1.–Location of preferred scales for scale age samples.

APPENDIX C: THEODORE RIVER CHINOOK SALMON RADIO TAG FORM, 2013

Appendix C1.–Theodore River Chinook salmon radiotagging data form, 2013.

Date	Time	Frequency	Code	Sex	Length (mm)	Floy tag no.	GV no.[a]	Comments
12 Jun	12:23	151.533	48	F	825	151	–	
12 Jun	12:24	151.544	49	M	552	152	–	
13 Jun	12:30	151.533	45	M	658	153	–	
13 Jun	12:30	151.544	45	M	790	154	–	
13 Jun	12:31	151.514	46	M	648	155	–	
14 Jun	16:00	151.533	46	F	640	156	1	
14 Jun	16:01	151.544	46	F	724	157	2	
15 Jun	15:15	151.524	46	F	772	158	3	
15 Jun	15:16	151.514	47	M	804	159	4	
16 Jun	13:00	151.533	47	M	615	160	5	
16 Jun	13:01	151.544	47	F	725	N/A	6	
17 Jun	13:20	151.524	47	M	812	161	7	
17 Jun	13:21	151.514	48	M	656	162	8	
18 Jun	15:10	151.524	48	F	764	163	9	
19 Jun	15:30	151.544	48	M	610	164	10	
19 Jun	15:31	151.514	49	M	615	165	11	
21 Jun	13:00	151.524	49	M	790	166	12	
21 Jun	22:30	151.533	49	M	780	167	13	
24 Jun	15:30	151.533	91	F	756	169	14	
24 Jun	15:31	151.544	91	M	867	171	15	
28 Jun	11:16	151.524	90	F	786	172	16	
28 Jun	11:17	151.533	90	F	798	173	17	
1 Jul	21:56	151.544	90	M	797	N/A	18	
1 Jul	21:57	151.514	91	M	819	N/A	19	
2 Jul	19:01	151.524	91	F	790	200	20	
2 Jul	19:02	151.514	92	M	813	N/A	21	
5 Jul	10:00	151.524	92	M	608	197	22	
6 Jul	16:00	151.533	92	M	824	196	23	
6 Jul	16:01	151.544	92	M	808	195	24	
7 Jul	13:00	151.514	93	M	704	194	25	
7 Jul	13:01	151.524	93	F	856	193	26	
7 Jul	19:35	151.544	93	F	588	192	27	
7 Jul	19:37	151.533	93	F	830	191	28	
8 Jul	10:30	151.544	43	M	852	190	29	
8 Jul	10:31	151.514	44	F	849	189	30	
8 Jul	19:05	151.533	98	M	887	188	31	
8 Jul	19:07	151.524	95	M	849	187	32	
10 Jul	10:50	151.514	97	F	825	N/A	33	
10 Jul	10:52	151.544	94	M	744	186	34	
10 Jul	10:54	151.524	97	M	603	185	35	
18 Jul	10:34	151.524	44	M	768	184	36	
20 Jul	11:00	151.533	44	M	610	183	37	
20 Jul	17:02	151.544	44	F	782	182	38	
20 Jul	17:03	151.514	94	F	803	181	39	
20 Jul	17:04	151.524	94	F	813	180	40	
20 Jul	17:05	151.533	94	M	565	179	41	
21 Jul	12:04	151.514	95	M	564	178	42	

[a] "GV no." is the genetic vile number.